

Smart Factory Personnel and Plant Safety Management System: A Study on Production Efficiency Re-evolution Based on Real-time Data Integration and Interaction Technology

Chun-Chang Liu^{1*}, Tien-Yin Chou², Kuo-Hao Tang³, Yao-Min Fang²

¹Ph.D. Program for Infrastructure Planning and Engineering Feng Chia University, Taichung, Taiwan (R.O.C.)

²GIS center, Feng Chia University, Taiwan

³Department of Industrial Engineering and Systems Management, Feng Chia University

Abstract: With the rise of Industry 4.0, smart factories have become vital to enhancing production efficiency and ensuring the safety of personnel and facilities in modern industrial settings. This study explores how advanced technologies and system integration can achieve digital and smart factory management. The smart factory management system integrates equipment monitoring, personnel positioning, and image recognition and possesses robust data analysis capabilities to support management decisions. This paper details the system's hardware and software requirements, environmental setup, and maintenance plan to ensure stable operation. The research results indicate that the smart factory management system can significantly improve production efficiency while greatly enhancing the safety of personnel and equipment, providing reliable assurance for enterprises in a highly competitive market.

Keywords: Personnel Safety Management, Plant Environment Safety, Real-time Data Integration, Production Efficiency Re-evolution

I. Introduction

The rise of Industry 4.0 has driven unprecedented transformation and upgrades in the manufacturing industry. As the core concept of Industry 4.0, smart factories leverage emerging technologies such as the Internet of Things (IoT), big data analytics, and artificial intelligence to digitize, automate, and intelligentize production processes. In the modern industrial landscape, establishing an efficient, secure, and reliable smart factory management system has become crucial to enhance production efficiency, ensure personnel and factory safety, and ultimately boost enterprise competitiveness. This research aims to achieve digitalization and intelligentization of factory management by integrating advanced technologies and systems. The proposed smart factory management system provides real-time information on equipment and personnel, enabling comprehensive monitoring and management through a centralized platform. This includes equipment operation status monitoring, fault diagnosis and early warning, personnel localization, and access control. The system also incorporates image and facial recognition technologies to strengthen factory security and prevent unauthorized personnel from entering sensitive areas. Moreover, the system possesses powerful data analytics capabilities, allowing instant presentation of key performance indicators (KPIs) to support management decision-making.

This research provides detailed hardware and software requirements and environmental configuration specifications for system implementation to ensure smooth deployment and operation. This encompasses database design and optimization, system log backup and recovery mechanisms, and exception-handling processes. By establishing a comprehensive system maintenance plan and providing timely technical support, the system can operate stably and efficiently in the long run, offering reliable informatization assurance for enterprise production and operation. This solution significantly improves production efficiency and dramatically enhances personnel and equipment safety protection, empowering enterprises to maintain a competitive edge in an increasingly fierce market.

II. Related Works

2.1 Factory Area Security Monitoring System

In the factory area security monitoring system, users can obtain a list of images from all cameras within a specific area by selecting that particular region. Suppose users need to confirm the exact location of a camera. In that case, they can click on the camera's icon, and the electronic map will display a flashing red circle to indicate the camera's position for reference. Users wishing to view an enlarged image from a specific camera can scroll up and down using the mouse to select the image window. Upon clicking, the system will automatically open a new window, presenting the real-time image from that camera facilitating detailed inspection and evaluation by

the users. The design of this function aims to enhance the efficiency and convenience of factory area security monitoring, enabling managers to quickly grasp the real-time situation in various areas within the factory and take necessary countermeasures promptly to maintain the safety and stable operation of the factory.

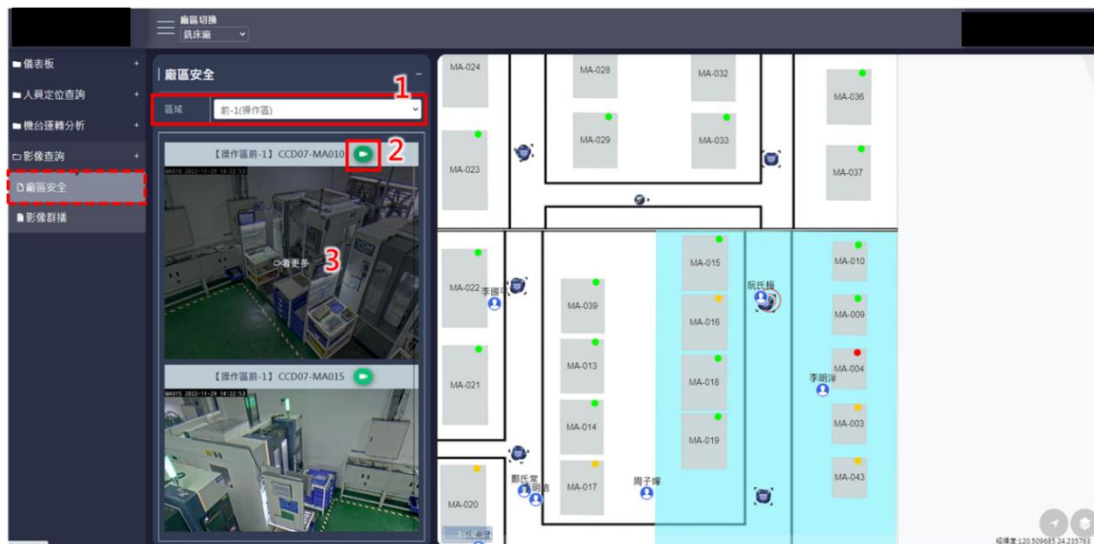


Figure 1 Factory Area Security Monitoring System Diagram

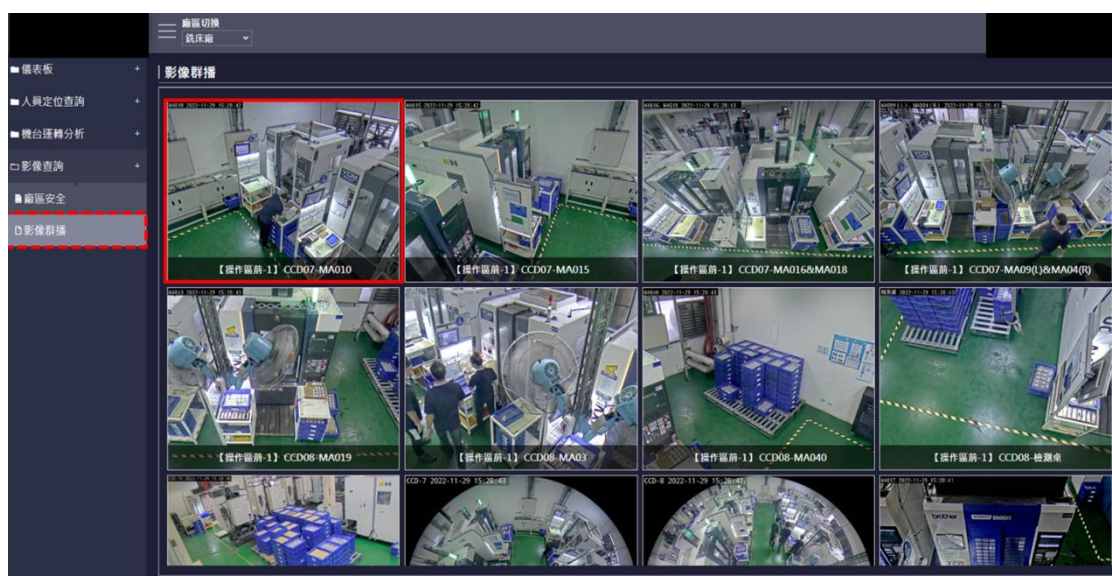


Figure 2 Factory Interior Image Carousel

2.2 System Administration Privilege Mechanism and Functional Module Management

System Administration (For System Administrator Privileges Only) Only system administrators can use this. Before using it, please log in using the login icon in the top right corner of the system window. Enter the administrator account, password, and verification code to access the system administration functions.

1. Functional Module Management: You can adjust the order of the functional modules on the left side through drag-and-drop operations. If a new functional module is added in the future, click the plus icon, enter the relevant information, specify the role permissions, and then click the confirmation button to complete the addition.
 - (a) Edit/Remove Roles Select the role you want to edit and adjust the functional module permissions corresponding to each role; you can check or select all. After the changes are complete, click the confirmation button to apply the changes. If you need to remove a role, click the delete button to execute.

2. Geographic Information Layer Management Used to manage system maps or related geographic information layer updates, modifications, or removal operations (such as cameras, etc.). This setting is mainly used to accommodate future functional expansion needs. It is recommended that the adjustment content be confirmed with the system developers first to avoid arbitrary changes or deletions that may affect the operation of the current system functions.

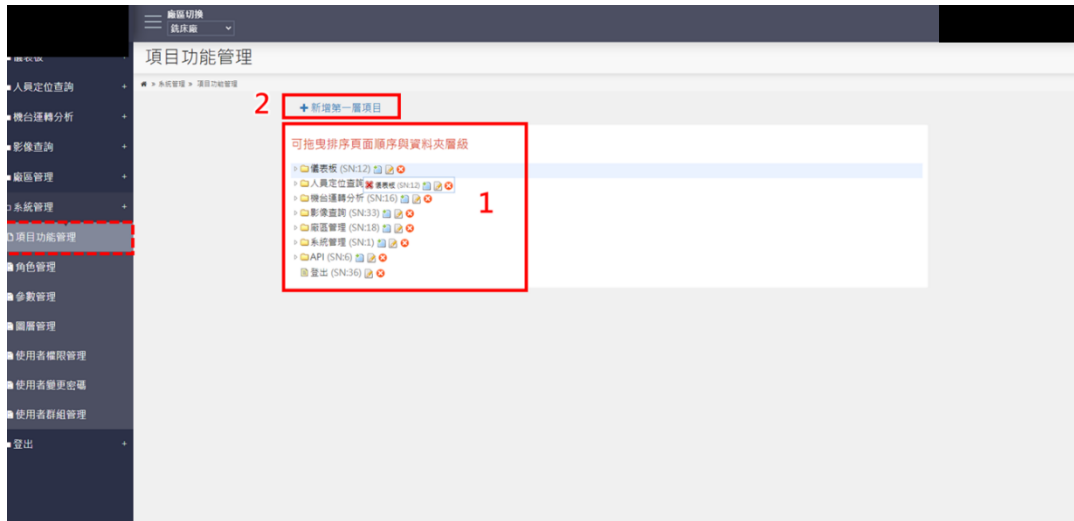


Figure 3 Feature Management Diagram

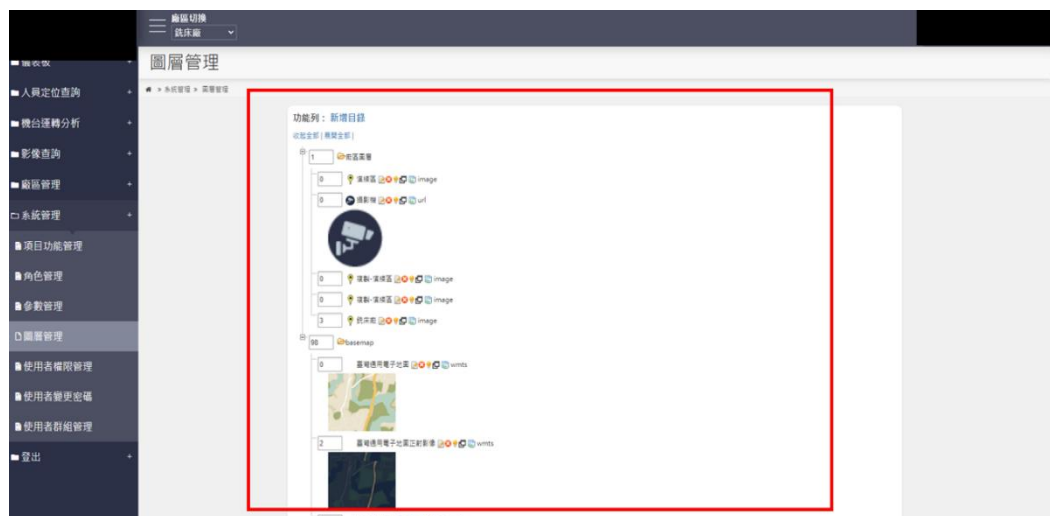


Figure 4 Camera Geospatial Information Management Diagram

III. Introduction to the Method

3.1 Personnel Location Query

I. Central Monitoring Console Module

- (1) Real-Time Operator Monitoring Sub-Module - Utilizing the personnel locating subsystem deployed within the factory, it obtains the total number of operators wearing wireless radio-frequency identification (RFID) devices in each manufacturing area in real time. - A quick navigation button is provided to directly switch to the "Personnel Location Inquiry" module, displaying the operators' detailed location information.
- (2) Production Equipment Operation Status Monitoring Sub-Module - Counts the total number of connected equipment on the production lines in each area. - Utilizes different colored signals (red, yellow, green, gray) to represent the real-time operation status of the equipment visually. - A quick navigation button is provided to switch to the "Equipment Operation Analysis" module, displaying real-time equipment operation information.
- (3) 24-Hour Abnormal Event Monitoring Sub-Module - Continuously monitors and records abnormal events occurring within 24 hours, including personnel location anomalies, equipment failure shutdowns, equipment maintenance delays, and personnel locating system non-responses.
- (4) Factory Area Visualization Interface Sub-Module - Through a two-dimensional floor plan of the manufacturing area, it intuitively displays the identification numbers of production equipment and the names of operators. - Visually represents the relative positions of personnel and equipment in real time.

II. Area Operation Dashboard Module

- (1) Area Workforce Distribution Analysis Sub-Module - Combines statistical data with pie chart visualizations to display the workforce distribution across different areas. - A quick navigation button is provided to switch to the "Personnel Location List" module for workforce allocation management.
- (2) Area Personnel Flow Monitoring Sub-Module - Utilizes bar charts to present personnel flow statistics for each area at half-hour intervals. - Monitors and analyzes personnel flow trends across different periods.
- (3) 24-Hour Personnel Abnormal Event Analysis Sub-Module - Based on the frequency of personnel location abnormal events triggered within 24 hours, it displays a bar chart ranking the top five operators with the highest occurrences. - Assists managers in monitoring the attendance status of operators.
- (4) Abnormal Event Detailed Record Sub-Module - Provides a list of abnormal events detailing the information of personnel involved in the abnormalities. - Clicking on the adjacent camera icon opens the surveillance footage of the corresponding area, allowing direct observation of the employee's work status.



Figure 5 Factory Area Dashboard Diagram

3.2 Production Efficiency Enhancement and Real-time Monitoring System

1. **Changeover Efficiency Analysis:** Changeover Efficiency Evaluation and Optimization Changeover efficiency analysis aims to evaluate the performance of machine changeover times before, after, and during maintenance periods. The system will display a detailed analysis list by selecting specific changeover intervals, areas, and machine numbers and clicking the button. To assist users in quickly interpreting the operational situation, the analysis results are presented using different colored indicators. Systematic changeover efficiency analysis can effectively identify bottlenecks in the changeover process, optimizing changeover operations and enhancing overall production efficiency.
2. **Message Transmission and Reception Statistics:** Message Transmission Monitoring and Tracking The message transmission and reception statistics function provides detailed information on all sent messages and statistical overviews of each message category, facilitating subsequent message querying and tracking. Users can query based on time, area, category (personnel, machine), event level (urgent, attention, and general), or keywords. After clicking the button, the system will display the delivery details and related statistical charts that meet the specified conditions. The system provides an icon for urgent messages (such as employee location timeout notifications). Clicking on it opens a new window displaying the work image of the employee's last known location, strengthening the real-time monitoring and problem-solving capabilities of message transmission and ensuring the smooth progress of production operations.



Figure 6 Changeover Efficiency Diagram



Figure 7 Message Transmission and Reception Statistics Diagram

4 Results and Discussion

4.1 Plant Safety Monitoring and System Management Access Control

1. Factory Area Security Monitoring System:

- 1) Real-time Video Surveillance By selecting a specific area, the system will instantly display a list of video feeds for that area. To confirm the location of a camera, users can click on the icon, and the map will indicate the camera's position with a flashing red circle. If users need to view an enlarged image, they can scroll up or down with the mouse and click on the video window, and the system will automatically open a new window for viewing.
- 2) Multi-Area Video Carousel The system supports simultaneous viewing of all cameras across various factory areas, significantly enhancing management efficiency and convenience. Users only need to click on the video window, and the system will automatically open a new window for detailed inspection.

2. System Management Access Control:

- A. System Administrator Privileges System management functions are restricted to users with system administrator privileges. Before use, administrators must authenticate their identity through the login icon located in the upper-right corner of the system window. Administrators can access the system management functions after entering their username, password, and verification code.
- B. Item Function Management and Expansion The system provides an intuitive graphical interface, allowing administrators to flexibly adjust the order of function items on the left side through click-and-drag operations. For future additions of new functions, administrators can click on input relevant data, set role permissions, and click the button to complete the function expansion.

This system effectively enhances factory area security management through real-time video surveillance and multi-area video carousels. Simultaneously, the system provides a refined access control mechanism to ensure the security of system management. The graphical interface allows administrators to easily manage and expand item functions, increasing the system's flexibility and adaptability to meet future management needs.



Figure 8 Factory Area Security Diagram



Figure 9 System Management Access Control Diagram

5 Conclusions

5.1 Conclusion

This study provides an in-depth analysis of the personnel and facility safety management system within smart factories, leading to the following conclusions:

(1) Importance of Real-Time Monitoring and Video Playback Functionality:

The system offers robust real-time monitoring and video playback capabilities, allowing users to view camera footage anytime. This feature enables managers to select specific areas, browse through video lists, and quickly locate particular camera positions, which is particularly beneficial in tracking historical footage during emergencies. The video carousel function allows simultaneous viewing of all camera feeds, significantly enhancing management convenience.

(2) Advantages of System Management and Functional Flexibility:

The system management features permit administrators to manage account logins and oversee the system effectively. The "project function management" feature allows administrators to adjust the order of tasks on the left panel, accommodating the expansion of system functionalities. Through simple configuration and role-based permissions, additional functions can be added to enhance system flexibility. The system's capability for continuous expansion and upgrades ensures it meets the ever-changing needs.

(3) Comprehensive Benefits of the Smart Factory System:

The system includes real-time monitoring, historical video retrieval, and multi-camera synchronous viewing and provides system administrators with functional management and flexibility to adapt to changing requirements. Implementing the smart factory system improves operational efficiency and safety within the factory.

In summary, the smart factory personnel and facility safety management system proposed in this study, with its features of real-time monitoring, video playback, and system management flexibility, can effectively enhance factories' operational efficiency and safety. This system offers reliable information security, providing enterprises a competitive edge in a highly competitive market.

References

- [1]. Muhammad Saqlain, Minghao Piao, Youngbok Shim 3 and Jong Yun Lee, Framework of an IoT-based Industrial Data Management for Smart Manufacturing, Journal of Sensor and Actuator Networks, pp. 1-21,2019
- [2]. Miguel Saez; Francisco P. Maturana; Kira Barton; Dawn M. Tilbury, Real-Time Manufacturing Machine and System Performance Monitoring Using Internet of Things, IEEE Transactions on Automation Science and Engineering, vol. 15, no. 4, pp. 1735-1748, Oct. 2018

- [3]. S. Yin, J. J. Rodriguez-Andina and Y. Jiang, "Real-Time Monitoring and Control of Industrial Cyberphysical Systems: With Integrated Plant-Wide Monitoring and Control Framework," in IEEE Industrial Electronics Magazine, vol. 13, no. 4, pp. 38-47, Dec. 2019